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EXPERIMENTAL INVESTIGATION ON RC BEAM SUBJECTED TO ELEVATED TEMPERATURE

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ABSTRACT

This project deals with behavior of reinforced concrete beams under the effect of elevated temperature. The reinforced concrete beam were subjected to elevated temperature 400 °C and 800 °C where chosen for 4.0 hours and 8.0 hours respectively. The present study investigates the effects of Conventional concrete and with 10% of cement been replaced by Metakaolin (MK) on all mechanical properties for M40 grade of concrete. In this project the materials properties of cement, sand and aggregates are tested. Cubes, cylinder and beam were casted for M40 grade of concrete and the compressive, tensile and flexure strength and behavior of RC beam (0.23mx 0.150mx1.5m) with respect to load versus deflection were tested and found out respectively.

Key words: Metakaolin (MK); elevated temperature; conventional concrete; crack width; Deflection.

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1. INTRODUCTION

As we know that concrete is widely used as construction material through the world. Due to high demand we should think of another materials also which have good mechanical properties as well pollution free. [1] Metakaolin (MK) is the cementetious material which are used as admixture to enhance the strength of concrete[2][3]. It is achieved through thermal treatment of kaolinitic clay at elevated temperature ranging from 500^{0}C -800^{0}C.Since the properties of concrete gets highly influenced when subjected to elevated temperature. The stiffness and strength are generally reduced as the temperature increases[4]. From all the method of addition of new materials with cement to develop the strength of concrete and

triumph HPC, using the Metakaolin is a moderately new approach. Specially MK is used in high blast furnace foundation industries, furnace walls chimney, runway for aircraft because of its high temperature resisting properties.[5]

The main objectives of this research

- The experimentation was carried out to attain all the mechanical properties of concrete with conventional concrete and concrete with Metakaolin (MK).
- To investigate deflection behavior of RC beams at elevated temperature for both CC and with partially replaced cement with MK.
- To study the crack width, ultimate crack and max deflection at elevated after contact to proposed temperature.

2. MATERIALS USED

2.1. Cement

The cement should be used as per IS specification. OPC 53 grade of cement is used.

Table 1 Physical Properties of cement

S.NO	Characteristics	Experimental Value
1	Fineness modulus	4.49
2	Specific gravity	3.148
3	Initial setting time	minutes

2.2. Fine Aggregate

Nearby Sand was used which is passing through 4.75 mm to the recommendation of IS 383-1970.

Table 2 Physical properties of fine aggregates

S.NO	Characteristics	Test result
1	Specific gravity	2.60
2	Zone of aggregate	Zone III

2.3. Coarse Aggregates

The coarse aggregate of size 10mm and 12mm were used for mix design and casting.

2.4. Metakaolin (MK)

Metakaolin (MK) is achieved through thermal treatment of kaolinitic clay at elevated temperature ranging from 500^0C -800^0C[5][7]. It is used to enhance the properties of concrete at elevated temperature. With 10% Metakaolin used throughout the experimental study.

Figure 1 Metakaolin (MK)

Table 3 Physical and Chemical properties of MetaKaolin

S.No.	Metakaoln Characteristics	Specification Requirement
1	Form / Appearance	Light brown colored fine powder
2	SiO_2	54.68%
3	Al_2O_3	44.15%
4	Particle size	< 2μm
5	Specific gravity	2.56

2.5. Super-Plasticizer

It is also known as retarder which are used in concrete mix to increase the workability by maintaining the optimum w/c ratio. Here, Ligno sulphonate chemical admixture is used as superplasticizer. The specific gravity is 1.09

2.6. Water

Water used as constituent of concrete mix, which not only vigorously contributes in the hydration of cement on the other hand, contributes to the workability of fresh concrete.

3. LITERATURE REVIEW

H.G. Mundle (Feb 2014) had investigated concrete specimens was exposed to elevated temperature 150 °C and 200 °after 14 and 28 days. The compressive strength of concrete with 24 hours (one day) & 72 hours (three day) of temperature after 28 days curing at 50°C,100°C, 150°C, 200°C was 35.84MPa, 40.74MPa, 42.66MPa, 42.96 MPa (one day) .[1]

Mohammad Mansour Kadhum (2014) has observed the behavior rectangular RC beam under, flame temperature between 50-700°C for the time period of 1.5hour. Ultrasonic pulse velocity test was conducted. It is found to be 28% at 400°C and after cooling it is 33%. when rigid beam were cooled by air and water respectively[3]. The crack width is also increases with increase in flame temperature.

Sreenivasulu1, Dr. K. Srinivasa Rao (2013) had investigated the behavior of M100 concrete when exposed to elevated temperatures and also the changes in properties of HSC subjected to heat for different durations of exposure. An oven with a maximum temperature of 300°C was used for exposing the specimens to different elevated temperatures. It was observed that 5 % decrease in residual mechanical properties with increase in temperature (27°C -250°C) for time period of 4 hours[4].

Beulah et al. (2012) had investigated additional of metakalion (MK) with cement changing the replacement level. They determined that the strength of the CC is to some extent inferior to the MK.[8]

4. METHODOLOGY

After intial testing of all the materials, we prepared the mix design for different trial for M40 grade and we go for casting of cubes,cylinder and prism(as per standard size).After7,14and 28 days of curing of the specimen for both conventional concrete and with 10% replacement of cement with metakolin(MK) testing has been done .After checking mechanical properties of concrete ,we go for casting of RC Beam of size (0.23mx 0.150mx1.5m).Curing of RC Beam done for 28 days .After painting (White Wash) of Beam ,we go for testing of RC beam

The reinforced concrete beam were subjected to two temperature stages of 400 °C and 800 °C in oven where chosen for period of 4.0 hours and 8.0 hours respectively. From that we find flexural strength of the beam with two point loading testing frame of maximum capacity 100T. and we find intial crack load ,ultimate crack load ,maximum deflection and crack width with given exposure of temperature of the specimen.

5. MIX PROPORTIONING

5.1. Mix Design for M40 Grade Concrete (Conventional)

Water	Cement	Fine aggregate	Coarse aggregate
158 lit	450 kg	644.371 kg	1121.02 kg
0.35	1	1.43	2.49

5.2. Mix Design for M40 Grade Concrete (Using 10% Replacement of Cement By Metakaolin)

Water	Cementitious Material		Fine aggregate	Coarse aggregate
	Cement	Metakaolin		
158 lit	405 kg	40.5 kg	642.473 kg	1165.015kg
0.39	0.9	0.1	1.58	2.87

5.3. Experimental Program for Testing of RC_Beam (0.23m x 0.150m x1.5m)

5.3.1. Casting & Curing of Specimen

The Specimen were casted using beam mould after the casted specimen are initiated for curing after 10hours and the mould is removed and the beam specimen are cured in the clear water for 28 days until they are taken out for testing as shown in fig. Before testing, beam identification is marked on the specimen for reference and coat of white wash is applied to the beam to facilitate the observation of cracking pattern.

Figure 2 Mould preparation

Figure 3 Casted beam

Figure 4 Curing of RC beam

Figure 5 White Coating

Figure 6 Beam kept under elevated temperature in high temperature furnace

5.3.2. Testing Preparation and Arrangement

The two point load test of the beam is carried out in the beam testing frame of maximum capacity 100T. The beam are taken out for testing at the end of 28 days and white washed as described earlier and kept ready. To measure the deformation of the beam dial gauge of least count of 0.01mm accuracy are fixed to the middle of the beam as shown in fig 5.5. The point were the dial gauge reading are to be taken are cleaned well.

Figure 7 Test set up

6. OSERVATION AND TABULATION

6.1. Mechanical Properties of Concrete

6.1.1. Compressive Strength

The compressive strength is tabulated in table 4

Table 4 Compressive strength of concrete

CONCRETE TYPE	COMPRESSIVE STRENGTH (N/mm^2)		
	7 days	14 days	28 days
Conventional concrete	34.44	46.49	51.66
Concrete with Metakaolin (10%)	37.87	46.18	54.65

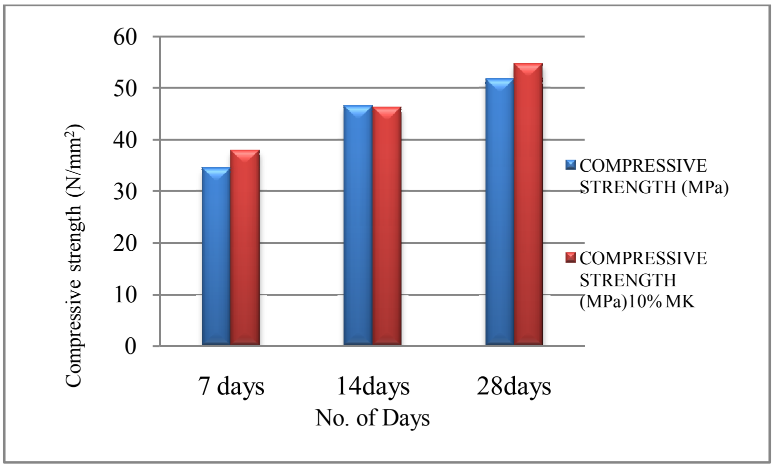

Figure 8 Compression strength of concrete

6.1.2. Split Tensile Strength

The split tensile strength was found out as tabulated in table 5

Table 5 Split tensile strength

CONCRETE TYPE	SPLIT TENSILE STRENGTH (N/mm^2)		
	7 days	14 days	28days
Conventional concrete	2.24	3.02	3.36
Concrete with Metakaolin (10%)	2.93	3.12	3.92

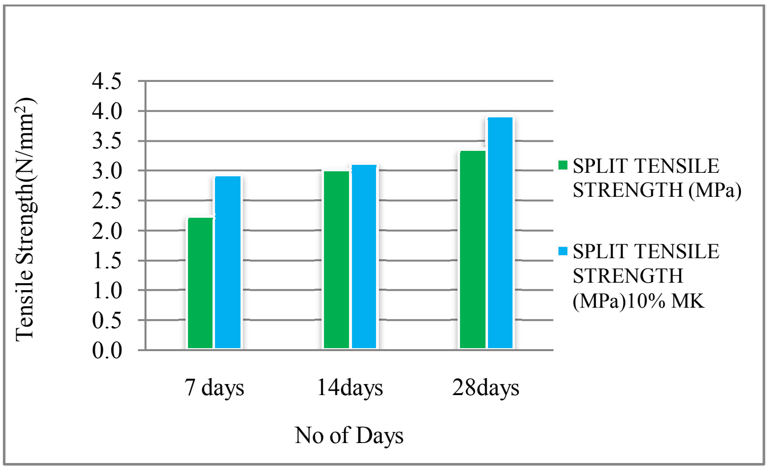

Figure 9 Split Tensile strength of concrete

6.1.3. Flexural Test

The flexural result is tabulated in table 6

Table 6 Flexural test of concrete prism

CONCRETE TYPE	**FLEXURAL STRENGTH (N/mm^2)**		
	7 days	**14 days**	**28 days**
Conventional concrete	4.33	5.85	6.5
Concrete with Metakaolin (10%)	5.08	5.98	6.9

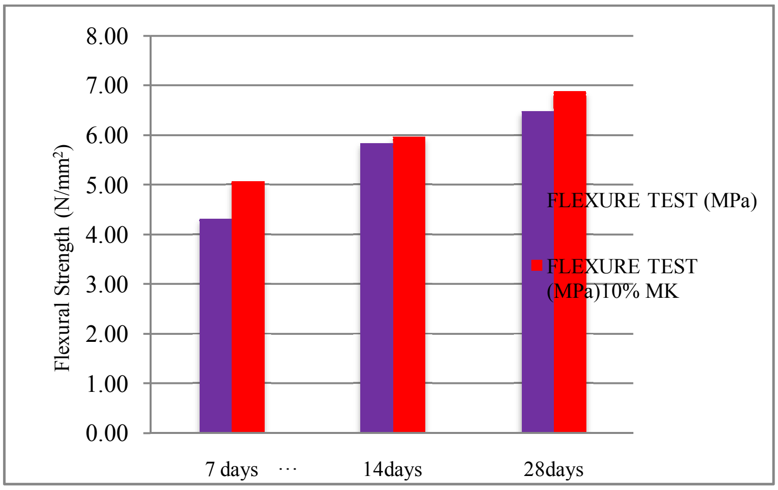

Figure 10 Flexural strength of concrete

6.2. Testing of RC Beam at Elevated Temperature

From the experimental investigation, deflection results are obtained for the application of typical load.[9]Following tabular column depicts the load v/s deflection for the RC beam for conventional concrete and with 10% replacement Cement with MK RC beam at heat furnace 400 ^{0} C and 800 0C for duration of 4 hours and 8 hours.

Table 7 Conventional Concrete

Loads	**Deflection**	**(Without Temp)**	**Load**	**Deflection**	**400^0c**	**Load**	**Deflection**	**800^0c**
(in kN)	(in mm)		(in kN)	(in mm)	^{0}C	(in kN)	(in mm)	^{0}C
0	0		0	0		0	0	
10	0.19		10	0.94		10	1.16	
20	0.35		20	1.47		20	1.89	
30	0.54		30	2.03		28	2.42	Initial crack load
40	0.75		40	2.8		30	2.57	
50	0.96		48	3.22	Initial crack load	40	3.23	
58	1.15	Initial crack load	50	3.47		50	3.9	
60	1.23		60	4.16		60	4.54	
70	1.39		70	4.94		70	5.19	
80	1.58		80	5.66		80	5.71	
90	1.82		90	6.31		90	6.28	
100	1.97		100	7.76		100	6.95	
110	2.18		110	9.02		110	7.94	
120	2.43		120	11.69		120	10.31	Ultimate crack load
130	2.71		124	13.04	Ultimate crack load			
140	3.11							
150	3.66							
160	4.38							
164	4.7	Ultimate crack load						

Table 8 With 10% Replacement of Cement with Mk at Elevated Temperature

Loads	**Deflection**	**(Without Temp)**	**Loads**	**Deflection**	**400^0c**	**Loads**	**Deflection**	**800^0c**
(in kN)	(in mm)		(in kN)	(in mm)	^{0}C	(in kN)	(in mm)	^{0}C
0	0		0	0		0	0	
10	0.14		10	0.63		10	1.01	
20	0.36		20	1.16		20	1.77	
30	0.63		30	1.68		22	2.01	Initial crack load
40	0.84		40	2.47		30	2.51	
50	1.11		48	3.01		40	3.17	
60	1.45	Initial crack load	50	3.42	Initial crack load	50	3.95	
70	1.75		60	3.93		60	4.47	
80	2.07		70	4.59		70	5.11	
90	2.37		80	5.34		80	5.64	
100	2.72		90	6.05		90	6.21	
110	3.14		100	7.71		100	6.81	
120	3.51		110	9.15		110	7.89	
130	3.89		120	11.98		120	10.25	Ultimate crack load
140	4.32		124	12.73	Ultimate crack load			
150	4.74							
160	5.09							
168	5.21	Ultimate crack load						

6.2.1. Load v/s deflection for Conventional RC beam

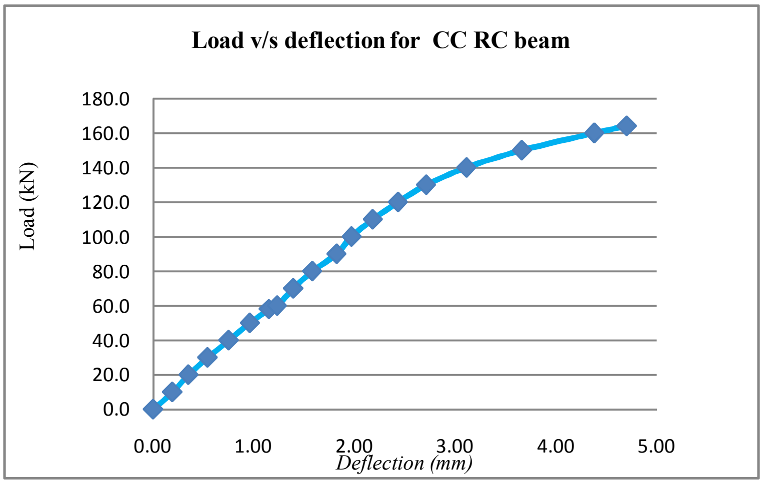

Figure 11 Load v/s deflection for CC RC beam

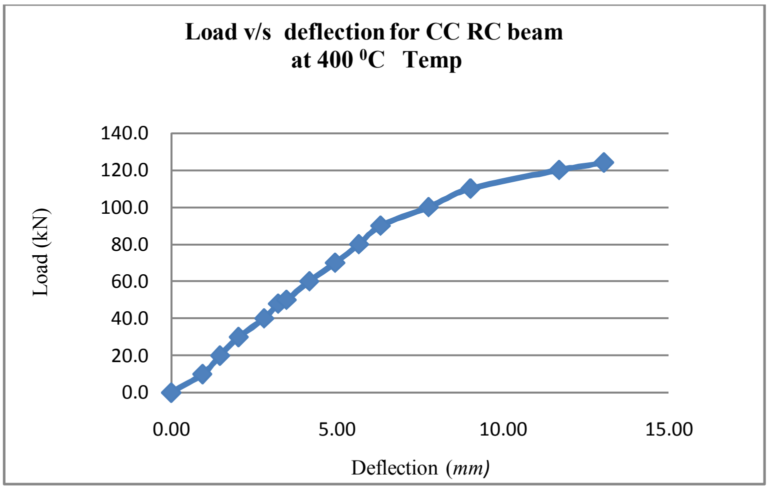

Figure 12 Load v/s deflection for CC RC beam 400 ^{0}C temp

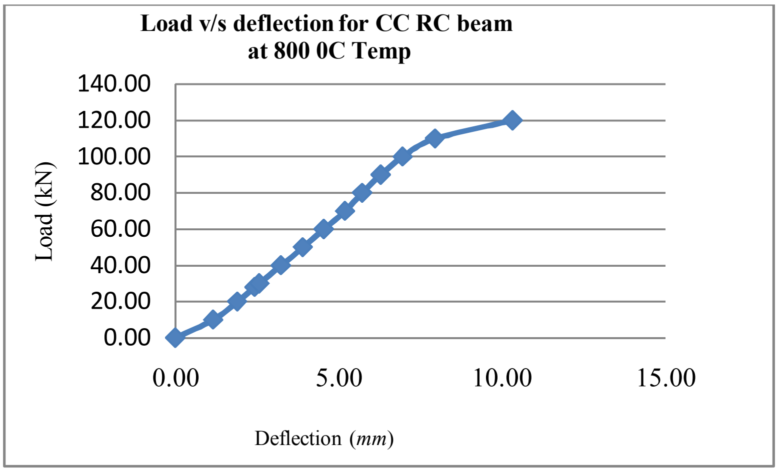

Figure 13 Load v/s deflection for CC beam at 800^{0}C

6.2.2. Load v/s Deflection for RC Beam with 10% MK

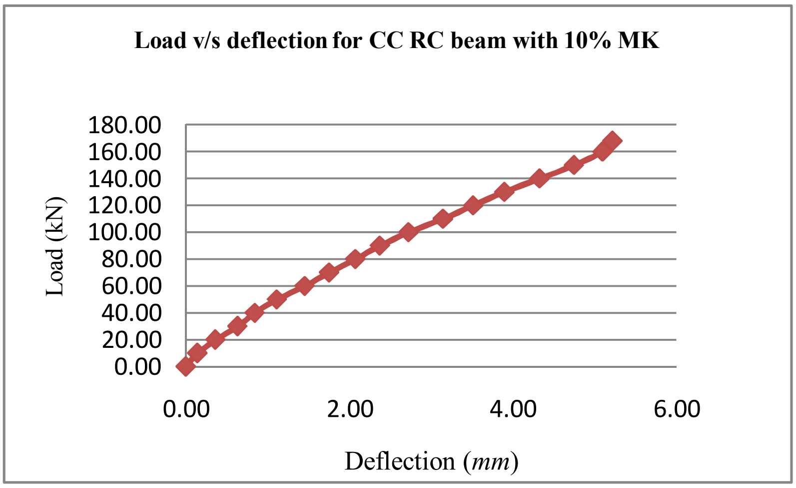

Figure 14 Load v/s deflection for CC RC beam with 10% MK

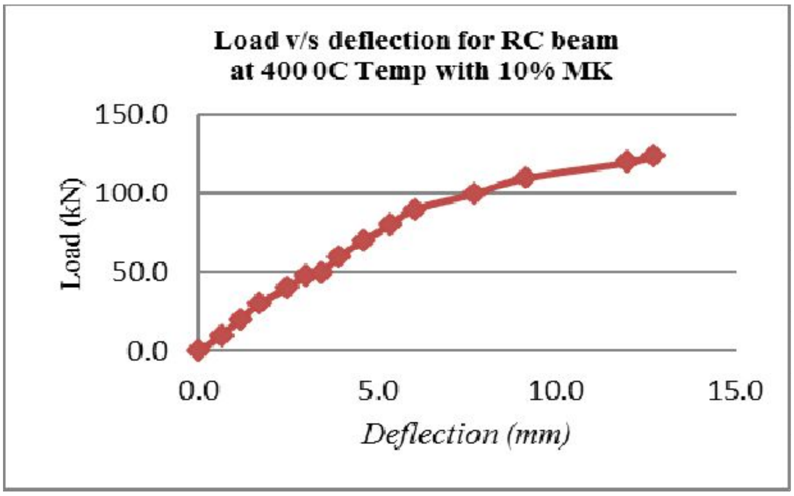

Figure 15 Load v/s deflection for RC beam at 400 ^{0}C temp with 10% MK

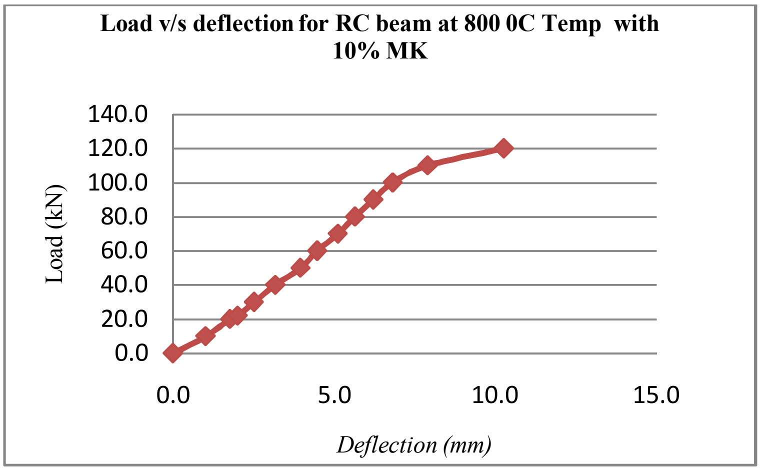

Figure 16 Load v/s deflection for RC beam at 800^{0}C temp with MK

7. RESULT AND CONCLUSION

Specimen name	Temperature ^{0}C	Intial load (kN)	Ultimate load (kN)	Max deflection (mm)	Max crack width (mm)
CC	0(without temp)	58	164	4.7	1.8mm
CC 1	400	48	124	13.04	2.4mm
CC 2	800	28	120	10.31	2.8mm
MK	0(without temp)	60	168	5.21	1.6mm
MK 1	400	50	124	12.73	2.2mm
MK 2	800	22	120	10.25	2.71mm

It leads to following conclusion from this research

- Metakaolin addition (MK) has resulted in enhanced early strength and ultimate strength of concrete.
- Strength of the CC is inferior than MKC.
- When the cement is substituted by 10% with Metakaolin for M40 grade of concrete, there is increment of 5.8% compression strength of concrete.
- Similarly , split tensile strength is also increased by 16.7 % when cement is substituted by 10% with Metakaolin for M40 grade of concrete.
- The flexural is also increased by 6.15% when the cement is replaced 10% with Metakaolin for M40 grade of concrete.
- So, the use of Metakaloin(MK) in concrete with replacement in cement as an admixture for an all structure can be used.
- The crack width also increases more in conventional concrete when compare to partial replacement of cement with MK concrete at elevated temperature.
- It also shows the loading capacity of CC is less as compared to the partially replaced MK reinforced concrete beam.
- Although the load acting on conventional concrete and MK at elevated temperature are same, the deflection behavior of CC is more than the partially replaced MK reinforced concrete beam.

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